Remarks

Reconsideration is requested in view of the preceding amendments and the following remarks. Upon entry of this amendment, claims 1-5, 7-17, 27, and 29-38 are in the application.

Claim Rejections for Indefiniteness

Claims 18-20 and 22-26 stand rejected as allegedly indefinite under 35 U.S.C. § 112, 2nd paragraph. The rejection of these claims is moot in view of the cancellation of these claims without prejudice.

Claim Rejections for Lack of Enablement

Claims 1, 6, 10, 18, 23, 27-28, and 33 stand rejected as allegedly not being enabled as required under 35 U.S.C. § 112, 1st paragraph. The rejection of claims 6, 18, 23, and 28 is moot in view of the cancellation of these claims without prejudice. The rejection of the remaining claims is traversed. Claims 1, 27, and 33 recite an X-ray time gate is situated to capturing an X-ray object image and claim 10 recites selectively transmitting an X-ray object image. According to the Office action, there is no evidence of electromagnetically induced transparency (EIT) for X-ray wavelengths, and therefore these claims are not enabled. However, none of these claims recite EIT, but instead recite only X-ray time gates or selective transmission of an X-ray object image. Representative examples of X-ray time gates that are known to those of ordinary skill in the art are described in, for example, R. Fitzgerald, "Ultrashort Laser Pulses Can Control X-Ray Switch," Physics Today at 16-18 (February 2002) (copy attached to this Amendment). Accordingly, one skilled in the art would be able to make and use the claimed invention, and withdrawal of the rejection of claims 1, 10, 27, 33 and their respective dependent claims is requested.

Claim Rejections for Lack of Utility

Claims 6, 18, 23, and 28 stand rejected as allegedly lacking utility under 35 U.S.C. § 101 for reciting electromagnetically induced transparency at X-ray wavelengths. The rejection of these claims is moot in view of the cancellation of these claims without prejudice. These claims also stand rejected under 35 U.S.C. § 112, 1st paragraph as one skilled in the art would allegedly not know how to use the claimed invention. This rejection is also moot.

Rejections in View of Combinations of McClean and Ham

Claims 18-20, 22-23, and 25-26 stand rejected as allegedly obvious from a combination of McClean, XP-002154943 ("McClean") and Ham, JOSA B 16:801-804 (1999) ("Ham"). The rejection of these claims is moot in view of the cancellation of these claims without prejudice.

Rejections in View of a Combination of McClean, Ham, and Hirose

Claim 24 stands rejected as allegedly obvious in view of a combination of McLean, Ham, and Hirose et al., U.S. Patent 5,680,429 ("Hirose"). This rejection is moot in view of the cancellation of these claims without prejudice.

Rejections in View of Combinations of Alfano, Hirose, and Hagelstein

Claims 1-2, 4-5, 7, 9-15, 27, 29-30, 32-34, and 37-38 stand rejected as allegedly obvious from a combination of Alfano, Hirose, and Hagelstein, U.S. Patent 4,873,439 ("Hagelstein"). This rejection is traversed. These references fail to teach or suggest all the features recited in these claims, and therefore fail to teach or suggest the claimed apparatus and methods.

Claim 1 recites an imaging apparatus that comprises an electromagnetic pulse source, a beam splitter that splits a pulse from the electromagnetic pulse source into a first portion and second portion, and an X-ray source that generates a beam in response to the first pulse portion. The beam generated by the X-ray source is directed toward an object for generating an X-ray object image and an X-ray time gate captures the X-ray object image in response to the second pulse portion. No combination of the Alfano, Hirose, and Hagelstein teaches or suggests such an apparatus. As noted in the Office action, Alfano and Hirose fail to teach or suggest an X-ray time gate that captures an X-ray object image in response to a second pulse portion. Hagelstein also fails to teach or suggest such an X-ray time gate. Instead, Hagelstein teaches that carrier density changes in a quantum well structure produce changes in refractive index so that an <u>optical</u> probe beam focused on a quantum well structure can be modulated. Col. 4, lines 5-28. According to Hagelstein, such changes in refractive index are strongest at wavelengths corresponding to energies just below the bandgap of the quantum well structure, i.e., at energies of about 1.45 eV (about 850 nm) for GaAs. Col. 4, lines 8-11. Thus, in a Hagelstein apparatus, X-rays (52) incident to a quantum well structure (50) produce refractive index changes that modulate an optical probe beam (41). Hagelstein does not teach or suggest an X-ray time gate, but instead teaches gating (modulating) an optical beam. The Office action states that Hagelstein's modulated optical beam is a replica of the X-ray object beam. Thus, not only does Hagelstein fail to

teach an X-ray time gate, Hagelstein teaches away form solving the problem of time gating an X-ray object beam by producing instead a related optical beam. Because no combination of Alfano, Hirose, and Hagelstein teaches or suggests an X-ray time gate, claim 1 and dependent claims 2-5 and 7-9 are properly allowable.

Claim 10 recites a method for producing an image of an object. The method comprises generating an electromagnetic pulse and splitting the pulse into a first portion and a second portion. An X-ray beam is generated in response to the first pulse portion and the X-ray beam is directed toward an object for generating an X-ray object image. The X-ray object image is selectively transmitted in response to the second pulse portion. No combination of Alfano, Hirose, and Hagelstein teaches or suggests such a method. As noted by the Office action, neither Alfano nor Hirose teaches or suggests an X-ray time gate, i.e., neither reference teaches or suggests selectively transmitting an X-ray object image in response to a second pulse portion. Hagelstein teaches using an X-ray beam to modulate an optical beam, but fails to teach or suggest selectively transmitting an X-ray beam as recited in claim 10. Therefore, claim 10 and dependent claims 11-17 are properly allowable.

Claim 27 recites an X-ray radar apparatus that comprises, in part, an X-ray time gate that captures a reflective X-ray object image in response to a second pulse portion from an electromagnetic pulse source. As noted above, no combination of Alfano, Hirose, or Hagelstein teaches or suggests an X-ray time gate, and claim 27 and dependent claims 29-32 are properly allowable.

Claim 33 recites, in part, a method for examining an object using an X-ray beam that includes capturing a reflective X-ray object image associated with a selected object depth with an X-ray time gate that is responsive to a second pulse portion from an electromagnetic pulse source. As noted above, no combination of Alfano, Hirose, or Hagelstein teaches or suggests an X-ray time gate, and claim 33 and dependent claims 34-38 are properly allowable.

Rejections in View of a Combination of Alfano, Hirose, Hagelstein, and Biswal

Claims 3 and 31 stand rejected as allegedly obvious from a combination of Alfano, Hirose, Hagelstein, and Biswal, U.S. Patent 5,757,839 ("Biswal"). This rejection is traversed. Because claims 3 and 31 depend from allowable base claims, these claims are allowable. In addition, Biswal fails to cure the deficiencies of Alfano, Hirose, and Hagelstein, as Biswal teaches optical pumping methods and apparatus, and not an X-ray time gate as recited in claims 3 and 31. For at least these reasons, claims 3 and 31 are properly allowable.

Rejections in View of Combinations of Alfano, Hirose, Hagelstein, and Ham

Claims 6, 28, and 35-36 stand rejected as allegedly obvious from a combination of Alfano, Hirose, Hagelstein, and Ham. The rejection of claims 6 and 28 is moot in view of the cancellation of these claims without prejudice. The rejection of claims 35-36 is traversed. Claims 35-36 recite, in part, methods for examining an object using an X-ray beam. The methods include generating an electromagnetic pulse and splitting the pulse into a first portion and a second portion. An X-ray beam is generated using the first pulse portion and directed toward an object. A reflective X-ray object image associated with a selected object depth is captured with an X-ray time gate that is responsive to the second pulse portion. No combination of Alfano, Hirose, Hagelstein, or Ham teaches or suggests and X-ray time gate configured to capture an X-ray object image. According to the Office action, Ham teaches a film of gating material (Pr:YSO) configured to transmit an object image in response to a pulse portion. However, Ham is directed to optical beams at optical wavelengths for optical memories, and Ham does not teach or suggest time gating an object image of any kind, and in particular, does not teach or suggest time gating an X-ray object image. For at least this reason, claims 35-36 are properly allowable over any combination of Alfano, Hirose, Hagelstein, and Ham.

Conclusion

In view of the preceding amendments and remarks, all pending claims are in condition for allowance and action to such end is requested.

Respectfully submitted,

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can sense the local environment, but they are sensitive to spin rather than charge order.

Theory

Steven Kivelson of UCLA comments that the high-temperature community is "currently interested in the general issue of competing orders. In many proposals about what's going on in high T_c, people say its key feature is a proximity to some ordered state." That state might be antiferromagnetism, ordered stripes of spin and charge regions, stripe orientational order, or a so-called staggered flux phase. (For a discussion of coexisting superconductivity and magnetism in other materials, see PHYSICS TODAY, September 2001, page 16.)

Shou-Cheng Zhang of Stanford University suggested in 1997 that the vortex core state would be the insulating antiferromagnetic state,[8] and in the same year he elaborated on that prediction with three other theorists.[9] The prediction followed from Zhang's SO(5) treatment of competing antiferromagnetic and superconducting orders, which are represented in his theory by 3D and 2D projections, respectively, of a 5D state vector. The prediction of this theory, that the field-induced antiferromagnetic moment is proportional to the applied field, helped pique interest in the vortex core state. Zhang and Jiang-Ping Hu have now relaxed the SO(5) symmetry to agree with experiments that find a fluctuating spin density wave rather than the static antiferromagnetic state he predicted earlier.[10]

Subir Sachdev of Yale University and various collaborators have been thinking about quantum phase transitions and magnetic order in the cuprates for many years, and the recent neutron-scattering experiments spurred them to examine the impact of an applied magnetic field on a magnetic transition. With Eugene Demler (Harvard) and Ying Zhang (Yale), Sachdev has interpreted the observed behavior in terms of the proximity of the superconducting phase to a phase with coexisting superconductivity and static magnetic order.[11] Increasing the magnetic field takes the superconducting phase very close to the phase with coexisting orders and leads to a strong enhancement of the low-energy spin fluctuations. The theorists predict that the static spin density wave signal should go as $H \ln H$. The data deviate from a linear H dependence in a manner that's consistent with this form. Before the STM experiment, Sachdev and a colleague had suggested that one might see a vortex nucleation of static charge order.[12]

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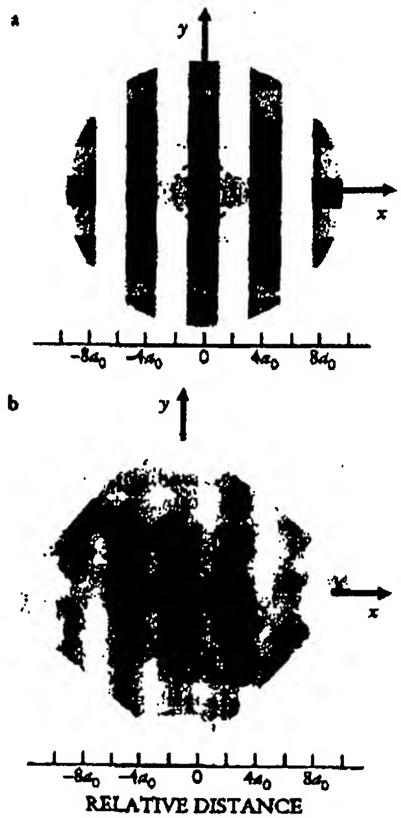

FIGURE 3. CHECKERBOARD IN DETAIL. (a) Schematic representation of a two-dimensional modulation of the charge density around a vortex core (dotted circle). The wavelength is four lattice spacings ($4a_0$). (b) Closeup of one of the vortices seen in Figure 2, rotated by 45°. Measured spectrum scaled to match the schematic above it. (Adapted from ref. 5.)

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Ultrashort Laser Pulses Can Control X-Ray Switch

In the molecular world of chemical reactions and conformational changes in biological and other molecules, events often happen on time scales from hundreds to thousands of femtoseconds—the typical period of molecular vibrations. Femtochemistry (described in PHYSICS TODAY, December 1999, page 19) uses ultrashort laser pulses, only a few tens of femtoseconds in duration, to probe electronic changes on such time scales. From these experiments, dynamics information can be extracted. But to obtain direct structural information, one needs a probe whose wavelength matches the angstrom scale of interatomic spacing: x rays are a prime candidate (see the article by Eric Galburt and Barry Stoddard in PHYSICS TODAY, July 2001, page 33).

The ability to direct pulses of x-ray synchrotron radiation using femtosecond lasers may open a new avenue for time-resolved x-ray studies.

Obtaining probes of appropriate wavelength, duration, and intensity is no easy matter, however. Laser-produced plasmas can generate sufficiently short bursts of x rays, but the bursts aren't highly collimated and have relatively low flux. Synchrotron sources, in contrast, produce trains of pulses that are tunable and have high brightness but, with durations of 10–100 picoseconds, are orders of magnitude too long.

Recently, a group of researchers from the University of Michigan, led by David Reis, Philip Bucksbaum,

Roy Clarke, and Roberto Merlin, has demonstrated a method of coherently modulating synchrotron x-ray pulses. Their technique might be scaled to produce subpicosecond switching.[1] "The preliminary experiments on this ultrafast switch are very promising," comments Jean-Claude Kieffer of the University of Quebec.

Exploiting the Borrmann effect

Key to the Michigan technique is the anomalous transmission of x rays through a crystal—the Borrmann effect. Usually, x rays are strongly attenuated in solids. But if properly oriented, a crystal's lattice planes can act as a waveguide: With the nodes of the x-ray electric field along the occupied lattice sites, attenuation is greatly reduced.

X rays incident on an appropriately oriented crystal generate a superposition of the anomalously transmitted mode and an orthogonal mode, transversely shifted by a quarter wavelength so that the field's antinodes are along the occupied lattice sites. For sufficiently thick crystals, this second mode is quickly absorbed, and only the first mode survives to reach the exit face of the crystal. There, it emerges as a forward beam, parallel to the incident direction, and a deflected beam of nearly equal intensity, as shown in figure 1. (This behavior underlies x-ray transmission interferometers, described in PHYSICS TODAY, July 2000, page 23.)

Working at the MHATT-CAT beam line at the Advanced Photon Source at Argonne National Laboratory, the Michigan group used 70-fs laser pulses to locally heat a germanium crystal. The resulting rapid thermal expansion triggered a narrow acoustic pulse that propagated through the crystal. The effect of the pulse, explains Reis, was essentially to split the crystal into two, with the compression and expansion regions of the acoustic wave defining a moving boundary between them (see figure 1).

The Borrmann effect is very sensitive to lattice distortions. Thus, when an x-ray pulse traveling through the Michigan crystal encountered the acoustic wave, the x-ray energy was redistributed between the two transmission modes. If this encounter occurred near the exit face of the crystal, both modes survived to leave the crystal. And because the modes travel at different phase velocities, the researchers could alter the superposition of modes at the exit face by controlling where in the crystal the x-ray pulse passes the acoustic wave. In that way, they could preferentially steer the x rays emerging from the crystal into the forward or deflected beam, as shown in figure 2.

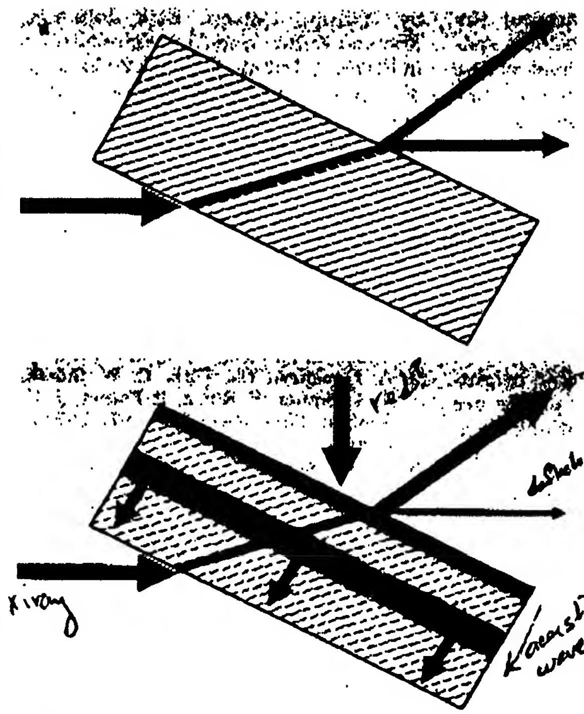

FIGURE 1. LASER-INDUCED X-RAY SWITCH. (a) When an x-ray pulse (green) is incident on an undisturbed germanium crystal, the crystal's lattice planes (dashed lines) can serve as waveguides, steering the pulse through to the exit face, where it emerges into a forward beam (parallel to the incident beam) and a deflected beam of nearly equal intensity. (b) A femtosecond laser pulse (red) heats the exit face of the Ge crystal, generating a thin acoustic front of compression (blue) and expansion (red) that travels through the crystal. The acoustic wave modulates the intensities of the forward and deflected x-ray beams. (Courtesy of Matt DeCamp.)

This technique, limited by the sound of the acoustic wave, currently gives control on time scales comparable to the synchrotron radiation pulse widths. With such switching speeds, controllable x-ray beamsplitters that can isolate a single pulse of synchrotron radiation are possible, but the method isn't fast enough for some time-resolved experiments. Reis and coworkers are optimistic, though, that by generating optical phonons using similar techniques, they will be able to achieve subpicosecond switching of the x-ray pulses.

Other techniques

Other approaches for producing femtosecond bursts of x rays for time-resolved x-ray studies are also being pursued. Among the most widely used is that of laser-produced plasmas. An intense ultrashort laser pulse can evaporate atoms at the surface of a solid. The resulting highly ionized plasma emits a burst of x rays, predominantly at discrete frequencies (the K_α lines). Bursts as short as 300 fs are readily achievable. Using this approach, Jeff Squier (University of California, San Diego) and colleagues[2] have observed simultaneous structural and electrical phase transitions in vanadium oxide (see PHYSICS TODAY, January 2002, page 9).

Robert Schoenlein and colleagues at Lawrence Berkeley National Laboratory have demonstrated a different method for obtaining short x-ray pulses at synchrotrons. They used a femtosecond laser copropagating with an electron bunch at the Advanced Light Source at LBL to give a kick in energy to a slice of the electron bunch. As

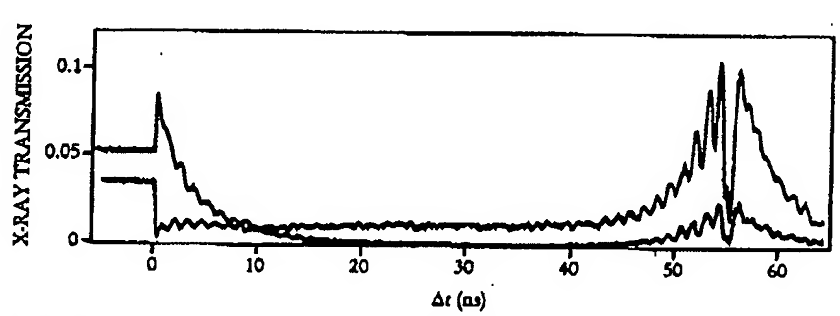

FIGURE 2. DIFFRACTION OF X RAYS into the forward (blue) and deflected (red) beams can be controlled by adjusting the time Δt between when the laser pulse and the x-ray pulse arrive at the germanium crystal. (Adapted from ref. 1.)

the electrons proceeded around the storage ring, that slice became spatially separated from the rest of the bunch. The radiation from the slice could consequently be isolated, producing an x-ray pulse 300 fs long. Additionally, the extraction of the electron slice created an ultrashort hole in the radiation emitted from the remaining electrons.[3]

Planned advances in synchrotron beam lines will create shorter electron bunches and, therefore, shorter pulses of emitted radiation. The upgrades will also increase the flux and brightness. Subpicosecond x-ray pulses are part of the design specifications for x-ray free electron lasers proposed for the fourth-generation TESLA collider at the German Electron Synchrotron (DESY) and for the Linac Coherent Light Source at SLAC (see the article by William Colson, Erik Johnson, Michael Kelley, and Alan Schwettman in PHYSICS TODAY, January 2002, page 35). And energy-recovery linacs under development can also support shorter electron bunches and thus will also generate ultrashort x-ray pulses.

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Correcting a Correction Weakens a Whiff of Supersymmetry

A recent corrective paper by particle theorists Masashi Hayakawa (KEK, Tsukuba, Japan) and Toichiro Kinoshita (Cornell University) is something of a cautionary tale.[1] Since the mid-1980s, Kinoshita and various colleagues have been laboring to calculate the anomalous magnetic moment of the muon (a_μ) from the standard model of particle theory with ever greater precision. The task has taken on particular urgency in the past year, as the pioneering Brookhaven experiment led by Vernon Hughes and Lee Roberts began to improve on earlier measurements of a_μ by more than an order of magnitude.

Hughes and company attracted considerable attention last year by reporting a 2.6-standard-deviation (σ) discrepancy between their first results and the standard-model prediction.[2] (See PHYSICS TODAY, April 2001, page 18.) The discrepancy was particularly tantalizing because its magnitude and sign hinted at the much-sought-after supersymmetric extension of the standard model. (See the article by Nima Arkani-Hamed, Savas Dimopoulos, and Georgi Dvali on page 35 of this issue.) There has thus been great anticipation of the fourfold increase in the Brookhaven data, expected this spring, which might confirm the discrepancy by raising it to a convincing 5σ.

Wet blanket

The new Hayakawa–Kinoshita paper, however, has somewhat dampened all this anticipation. The standard-model prediction is a sum of Feynman-graph terms representing ever smaller higher-order corrections. Kinoshita and collaborators have, in recent years, worked particularly on the contribution of virtual π^0 mesons to the scattering of virtual photons off one another. And what they tell us in their new paper is that, ever since 1995, they and other theorists have been getting the sign of this so-called hadronic light-by-light scattering term wrong! Now we are told that it should be an additive rather than a subtractive correction to a_μ.

The term contributes less than a part per million to a_μ. But the impact of changing a sign is, of course, twice the magnitude of the problematic term. And in this case, with an extraordinarily precise experiment confronting a similarly precise theoretical calculation, flipping the sign is enough to bring the standard-model prediction up to within 1.6σ of the measurement. So now, barring statistical flukes, the anticipated fourfold increase in the Brookhaven data is not likely to yield a discrepancy much greater than 3σ. That could leave the issue of a_μ as a harbinger of "new physics" in limbo for some time to come.

The culprit appears to have been a nonstandard phase convention well hidden in the bowels of the symbolic-manipulation program FORM used by Hayakawa and Kinoshota and many other theorists. FORM, a descendant of the Schoonschip program initiated by Martinus Veltman in the 1960s (see PHYSICS TODAY, December 1999, page 17), follows the Dutch tradition of multiplying the elements of the conventional Levi-Civita tensor $\varepsilon_{\alpha\beta\gamma\delta}$ by i. Ignoring this ethnic idiosyncracy creates no problems in the purely quantum-electrodynamic calculations for which FORM has been used by Kinoshita and others with great success. But the pseudoscalar character of the π^0 that dominates the hadronic light-by-light scattering term requires contractions of Levi-Civita tensors that give the wrong sign if one doesn't take careful account of the unusual phase convention.

Hayakawa and Kinoshita discovered this calculational landmine by exhaustively scouring FORM after Marc Knecht and Andreas Nyffeler at the University of Marseille reported in November that they had gotten a plus sign for the hadronic light-by-light term with a different symbolic-manipulation program called REDUCE.[3] Furthermore, they and colleagues at Marseille have also produced a convincing qualitative argument, based on effective low-energy field theory, for why the hadronic light-by-light correction has to be positive.[4]

The sign of the hadronic light-by-light correction to a_μ has a long and bumpy history. Kinoshita originally assigned the correction a plus sign in 1985. But he changed it to a minus sign 10 years later, and most other theorists working on the problem followed this about-face, even though there were shaky plausibility arguments in favor of a plus sign. But in the end, physics once again proves itself an admirably self-correcting discipline.

The theoretical prediction having now crept closer to the measurements, it would seem harder for the experimenters to ferret out new physics beyond the standard model. But new hadron-production data from several low-energy electron–positron colliders should soon shrink the theoretical uncertainty of the lowest-order hadronic correction to a_μ, thus giving any new physics a better chance to peep through.[5]

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